

We claim:

1 1. A computer-implemented method for animating an image based on a
2 scene description that includes one or more geometric objects and one or more particle
3 systems, the method comprising:

4 generating a plurality of cutout particles, each cutout particle corresponding
5 to a geometric object in the scene description;

6 rendering the particle systems with the cutout particles to generate a particle
7 image, wherein at least some cutout particles occlude particles of the
8 particles systems; and

9 compositing the particle image with an image of the geometric objects to
10 create a composited image.

1 2. The method of claim 1, wherein generating a plurality of cutout particles
2 comprises:

3 rendering the geometric objects to produce a depth map, the depth map
4 including a plurality of entries that each indicate a distance to a
5 nearest geometric object from a camera position in a particular
6 direction; and

7 generating cutout particles from at least some of the entries in the depth map,
8 each cutout particle corresponding to an entry in the depth map in
9 three-dimensional space.

1 3. The method of claim 2, wherein the cutout particles are generated at a
2 higher resolution than the particle image.

1 4. The method of claim 2, wherein the cutout particles are generated at a
2 higher resolution than the particle image along any silhouette edges of the depth map.

1 5. The method of claim 1, wherein generating a plurality of cutout particles
2 comprises sampling the geometric objects at a higher resolution than the particle image
3 at least in areas where aliasing is likely to occur.

1 6. The method of claim 1, wherein the rendering comprises:
2 for at least some of the particles of the particle systems and at least some of
3 the cutout particles, performing a compositing operation to determine
4 a coloring or an occluding effect of the particle on one or more pixels
5 of the particle image.

1 7. The method of claim 6, wherein the compositing operation is performed
2 for the particles from the farthest particle from a camera position to the nearest particle.

1 8. The method of claim 6, wherein the particles of the particle systems have
2 coloring effects on at least one pixel of the particle image and the cutout particles have
3 occluding effects on at least one pixel of the particle image, a coloring effect tending to

4 accumulate color for the pixel and an occluding effect tending to block any accumulated
5 color for the pixel.

1 9. The method of claim 1, wherein the rendering comprises:
2 combining the particles from the particle systems and the cutout particles into
3 a list;
4 sorting the list by each particle's distance from a camera position; and
5 for each particle in the list, from the farthest to the nearest, determining a
6 coloring or an occluding effect of the particle on one or more pixels of
7 the particle image.

1 10. The method of claim 1, wherein the rendering comprises:
2 combining the coloring effects of the particles of the particle systems and the
3 occluding effects of the cutout particles to determine the color for a
4 plurality of pixels in the particle image.

1 11. The method of claim 1, wherein the rendering comprises:
2 a step for resolving the coloring effects of the particles of the particle systems
3 and the occluding effects of the cutout particles based on the depth of
4 the associated particles.

1 12. The method of claim 1, wherein the compositing comprises alpha
2 blending the particle image with a rendered image of the geometric objects.

1 13. The method of claim 1, wherein the rendering comprises:
2 for each particle, determining which pixels in the particle image the particle
3 covers and an amount of the pixel covered, as seen from a camera
4 position.

1 14. The method of claim 13, wherein the rendering comprises:
2 computing a depth of field adjustment for a cutout particle.

1 15. The method of claim 13, wherein the rendering comprises:
2 computing a motion blur adjustment for a cutout particle.

1 16. A computer-implemented method for rendering one or more particle
2 systems to produce a particle image to be combined with a second image, the method
3 comprising:
4 generating a plurality of cutout particles associated with a three-dimensional
5 position of objects in the second image;
6 for each of a plurality of pixels in the particle image, computing a list of
7 coverage layers for the pixel, where each coverage layer in the list of
8 coverage layers indicates an accumulated color value due to one or
9 more particles of a particle system and an amount occluded by one or
10 more cutout particles; and

11 determining the color of the pixels based on their associated coverage layer
12 list.

1 17. The method of claim 16, wherein each list of coverage layers is generated
2 by processing the particles in order from farthest from a camera position to nearest.

1 18. The method of claim 17, wherein computing a list of coverage layers for a
2 pixel comprises:
3 adding a new coverage layer for a particle from a particle system that follows
4 a cutout particle in the processing.

1 19. The method of claim 16, wherein generating the cutout particles
2 comprises:
3 computing a depth map for the second image; and
4 generating a cutout particle for at least some entries in the depth map, each
5 cutout particle being having a position in three-dimensional space
6 corresponding to the depth map entry.

1 20. The method of claim 19, wherein at least portions of the depth map have
2 a higher resolution than the particle image.

1 21. The method of claim 16, wherein the cutout particles are generated at a
2 higher resolution than the particle image.

1 22. The method of claim 16, wherein generating a plurality of cutout particles
2 comprises sampling geometric objects in the second image at a higher resolution than the
3 particle image at least in areas where aliasing is likely to occur.

1 23. A computer program product comprising a computer-readable medium
2 containing computer program code for performing any one of the methods of claims 1
3 through 22.

1 24. A system for animating an image based on a scene description that
2 includes one or more geometric objects and one or more particle systems, the system
3 comprising:

4 a geometry renderer for rendering the geometric objects in the scene

5 description to generate a geometry image;

6 a cutout particle generator that generates a plurality of cutout particles, each

7 cutout particle corresponding to a geometric object in the scene

8 description;

9 a particle renderer for rendering the particle systems of the scene description

10 and the cutout particles to generate a particle image, wherein at least

11 some cutout particles occlude particles of the particles systems; and

12 a compositor that combines the geometric image and the particle image to

13 form a composited image.

1 25. The system of claim 24, wherein the geometry renderer generates a depth
2 map for the geometric objects in the scene description, and the cutout particle generator
3 generates the cutout particles based on the depth map.

1 26. The system of claim 25, wherein the cutout particle generator generates
2 the cutout particles at a higher resolution than the particle image at least in areas where
3 aliasing is likely to occur.

1 27. The system of claim 24, wherein the particle renderer processes the
2 particles from the farthest particle from a camera position to the nearest particle.

1 28. The system of claim 24, wherein the particle renderer is configured to:
2 combine the particles from the particle systems and the cutout particles into a
3 list;
4 sort the list by each particle's distance from a camera position; and
5 for each particle in the list, from the farthest to the nearest, determine a
6 coloring or an occluding effect of the particle on one or more pixels of
7 the particle image.

1 29. The system of claim 24, wherein the particle renderer is configured to
2 combine the coloring effects of the particles of the particle systems and the occluding

3 effects of the cutout particles to determine the color for a plurality of pixels in the
4 particle image.

1 30. The system of claim 24, wherein for each of a plurality of pixels in the
2 particle image, the particle renderer computes a list of coverage layers for the pixel,
3 where each coverage layer in the list of coverage layers indicates an accumulated color
4 value due to one or more particles of a particle system and an amount occluded by one or
5 more cutout particles.

1 31. The system of claim 24, wherein the compositor alpha blends the particle
2 image and the geometry image to form the composited image.